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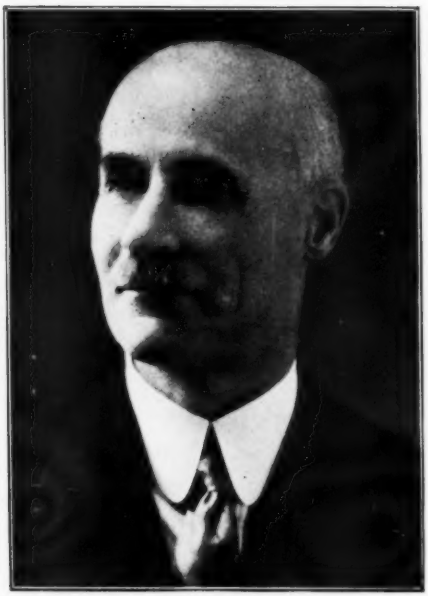
PLATE XV



EDWIN THEODORE WHITE (1869-1929)

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EDWIN THEODORE WHITE (1869-1929)

By H. R. KINGSTON

On Saturday, April 6, Dr. Edwin T. White, Secretary-Treasurer of the London Centre of the R.A.S.C., died very suddenly at his home, 34 Marley Place, London, Ont. Up to the evening of his death he had apparently been in his usual good health. During the early part of the week he had attended the meetings of the Ontario Educational Association in Toronto. On Saturday he worked in his garden and later went for a motor drive. Feeling a little indisposed in the evening, he retired early and an hour or so later he passed away before medical aid could be obtained.

Dr. White was a charter member of the London Centre, and had been its efficient Secretary-Treasurer since its formation in 1922. He contributed frequently to its programme and in every possible way endeavoured to make it a success. In 1928 he was elected a member of the General Council of the Society.

As an educationist Dr. White was favourably known throughout the province of Ontario; and he had served as president of the Training Section of the Ontario Educational Association.

He was born in Oakwood, near Lindsay, in 1869, and received his early education in the public schools and the Collegiate Institute of Lindsay. Proceeding to the University of Toronto, he followed the course in Mathematics and Physics and graduated in Arts in 1899. He became a teacher of mathematics in the Pembroke High School and later served for several years as Inspector

of Public Schools for Renfrew County. Since 1913 Dr. White had been on the staff of the London Normal School as Assistant Principal and Mathematics Master. In 1922 he obtained the degree of Doctor of Pedagogy at the University of Toronto. In addition to his work at the Normal School he lectured in Psychology at the University of Western Ontario and to the nurses-in-training at Victoria Hospital in the Institute of Public Health.

Dr. White was a member of the Canadian Club, a past-president of the Baconian Club and a member of the Masonic order. He rendered valuable service on the official board of Metropolitan United Church, and was for some time superintendent of the Sunday school.

At a memorial meeting of the London Centre, held in the London Life Building, fitting tribute was paid to the sterling character and marked ability of Dr. White. He was a man of high ideals, faithful and efficient in all his work, a man of deliberate and sound judgment and of kindly and delightful personality. As one member remarked, "Truly he was one of God's noblemen". The members of the London Centre feel that in his death the Society has lost one of its strongest supporters and most gifted friends.

In 1904 Dr. White married Clara Dunlop Perrett, of Pembroke. She survives him; also a daughter Evelyn, a graduate of the University of Western Ontario and now a student at Simmons College, Boston; and a son Lewis, who is completing his second year in the Faculty of Forestry in the University of Toronto.

University of Western Ontario,
London, Ont.

THE QUALITY OF THE LIGHT OF THE ECLIPSED MOON

By P. M. Millman

It is a well-known fact that during a total eclipse of the moon our satellite has a dull copper-red hue, caused by the light refracted into the earth's shadow by our atmosphere. The blue light has been absorbed to a greater extent than the red, and hence the longer wavelengths predominate, giving the moon a reddish colour. One sometimes sees references to the fact that the moon has a blue appearance as it is entering the shadow, a condition just the reverse of that when it is totally eclipsed. It was thought that it would be interesting to study the variation of intensity in the different parts of the spectrum during the total eclipse of the moon on Nov. 27th, 1928.

This was done by exposing a photographic plate to the light of the moon during the time of eclipse, utilizing light filters. The results obtained should be regarded as of a qualitative nature rather than quantitative, as the investigation was hastily conceived and many points in the method of procedure would have been changed had there been a greater time for preparation. The apparatus used was very simple. A box, 8 inches long, was fitted with a plate-holder in one end while a hole of 2.5 inches diameter was cut in the other. When the plate was exposed this was turned directly to the moon by means of a small finder at the side of the box, and in this way only the light of a definite portion of the sky around the moon could reach the plate. To enable a number of exposures to be made on one plate, a set of five small rectangular holes was cut in a card. One was left clear and the other four were covered by pieces of the different gelatine filters used. The latter were designated as follows:—

Designation	Filter	Transmission Limits	Effective Mean λ
Blue	Wratten 49 C4	λ3600 — λ5000	λ4490
Green	Wratten 58 B2	λ4800 — λ6200	λ5400
Red	Wratten 25	λ5800 —	λ6300±
Dark Red		λ6000 —	λ6400±

The card, with the filters attached, was placed before the plate when exposed and by shifting its position 10 complete sets of exposures could be obtained on each plate. The plates used were Ilford Soft Gradation Panchromatic, speed H.D. 700, and the exposures were either 20 or 30 sec. with a few exceptions. Five plates were taken, one before the central phase, and four after. The sky was partially covered by clouds during the first half of the eclipse and the first plate has been excluded from all the results. The four remaining plates were taken under perfect weather conditions. (See Plate XVI.)

A sensitometer, in which light is admitted through holes of varying aperture giving a total range of intensity of 50 to 1, was used to obtain density patches corresponding to standard intensities. The sensitometer patches were placed on the plates using a 30 sec. exposure with a two-hundred watt electric light. The plates were all developed together in Metol Hydrokinon developer at 15° C. for 12 minutes.

The photometer used in measuring the intensities of the patches was visual and employed a sliding neutral-tint wedge with a scale attached. It was considered that this gave as great accuracy as was obtained in the rest of the investigation. Both moon patches and sensitometer patches were measured in terms of the photometer readings, which formed an arbitrary scale of darkening. The readings of the sensitometer patches for the five plates were averaged and a smooth curve drawn through these mean points, giving a relation between intensity of source and photometer scale. A small correction, determined for each plate, was now applied to all the readings of the moon patches to reduce them to this standard curve. The intensities of the moon patches were read directly from it. (The scale of intensity is relative only and depends upon the construction of the sensitometer. No attempt has been made to give it absolute values.)

Before we can plot these intensities we must correct for the length of exposure. It was decided to reduce every observation to a standard exposure of 30 sec., since this was used in 50% of the exposures on the moon and in applying the sensitometer patches.

It has been shown by investigators at the Eastman Laboratories that the Schwarzschild expression for plate darkening, $*D = It^p$, holds only approximately for a wide range of intensities. It has been found, however, that for the plates in question p does not vary greatly over a range of intensity such as that encountered here and it was assumed constant in this case. In any event the value of p is of the nature of secondary correction since almost all the exposures were of 20 or 30 sec. The value of p was determined by least squares from a series of exposures taken on the moon at the end of the eclipse and ranging from ½ sec. to 30 sec. From these and former laboratory investigations the mean value of .87 was adopted for p for all filters except in the case of the dark red, where .99 was used. The intensities of the moon patches were reduced to the standard 30 sec. exposure in every case.

We now have a series of intensities of moonlight through each of the four filters reduced to the same scale. These intensities have been plotted against Eastern Standard Time in the four accompanying graphs. The small circles are individual observations, the large circles are normal places, of observations taken three by three. The use of normal places for the upper parts of the curves was necessitated by the fact that the readings of higher intensity are less accurate than the others and deviate more from a smooth curve. The short vertical line represents, in each case, the time at which the moon left the umbra. The elements of the eclipse were as follows:—

Middle of Eclipse	4.01 a.m. E.S.T.
Total Eclipse Ends	4.29 a.m.
Moon leaves Umbra	5.39 a.m.
Moon leaves Penumbra	6.38 a.m.

It will be noticed that while the curve for the red light is at first of about the same height as that for the blue, it rises much more rapidly. The ratios between the intensity of light through the various filters are given below for every ten minutes.

*D, plate darkening; I, intensity of source; t, time of exposure; p, a constant, depending on kind of plate.

FIG. 1

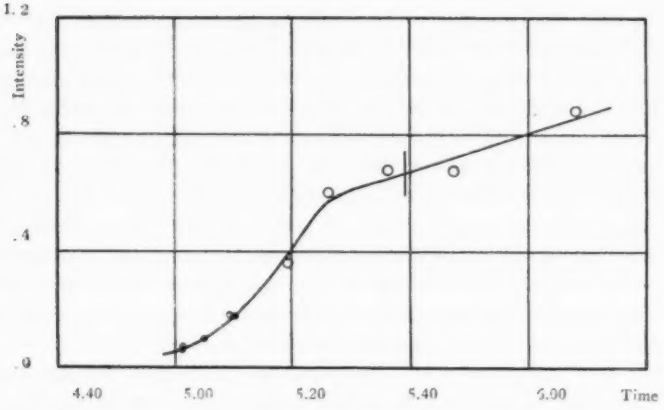

Fig. 1. Intensity of the moonlight, after passing through the blue filter, at succeeding stages of the eclipse. The times are Eastern Standard.

FIG. 2

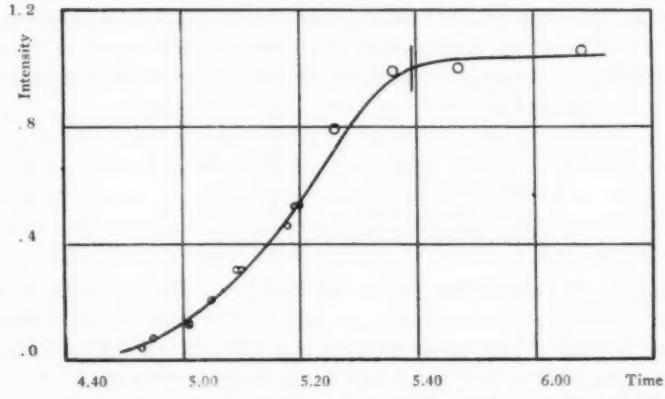

Fig. 2. Intensity of the moonlight, after passing through the green filter, at succeeding stages of the eclipse. The times are Eastern Standard.

FIG. 3

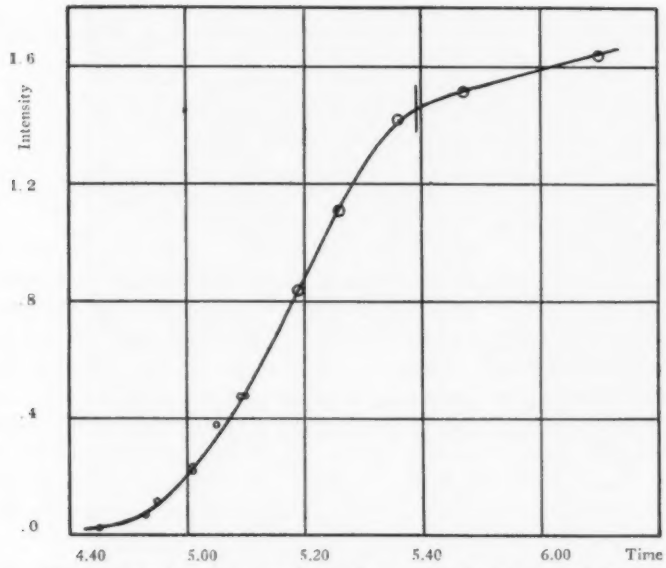

Fig. 3. Intensity of the moonlight, after passing through the red filter, at succeeding stages of the eclipse. The times are Eastern Standard.

FIG. 4

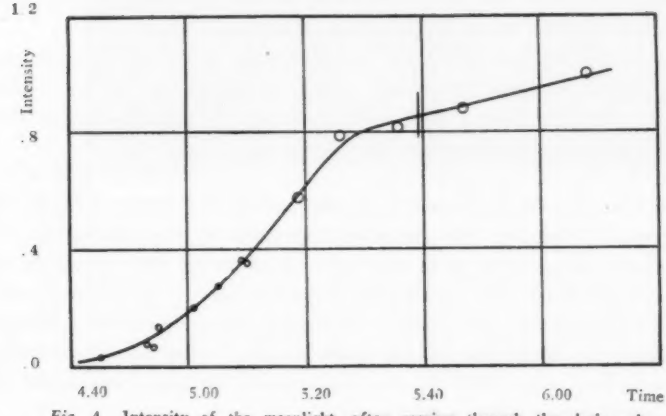

Fig. 4. Intensity of the moonlight, after passing through the dark red filter, at succeeding stages of the eclipse. The times are Eastern Standard.

Time	Dark Red/Blue	Red/Blue	Green/Blue
4.50 a.m.		.71	.43
5.00	.32	1.10	.63
5.10	.49	1.35	.78
5.20	.66	1.42	.87
5.30	.76	1.57	1.05
5.40	.78	1.71	1.16
5.50	.81	1.69	1.13
6.00	.83	1.66	1.08

It is seen at once that the blue light bears a far greater proportion to the red light at 4.50 a.m. than an hour later. To test whether this is owing to a variable sensitivity of the plate the set of exposures previously referred to, and taken at the end of the eclipse, were plotted in the same manner as the above curves. In this case the above three ratios remained constant (within the limits of accidental error) over a similar range of intensities. Hence it seems evident that the above results represent a real change in the relative intensity of blue and red moonlight as the moon leaves the umbra.

Another point must be considered. During the time these observations were made the zenith distance of the moon was increasing, and it might be argued that the increase in intensity of red light was owing to selective atmospheric absorption. This is negatived by the two following considerations:

1. From the measures of the observations obtained while the moon was entering the umbra a similar change in intensity ratio was noticed, the blue intensity increasing though the zenith distance was then also increasing.

2. During the greatest change in the ratio Red/Blue, 4.50 a.m.-5.40 a.m., the moon passed from altitude 27 degrees to altitude 18 degrees. Assuming the selective absorption of the atmosphere to be the same at night as in the day and adopting Abbot's values as determined from his work on the solar constant, it was found from rough calculation that selective absorption would produce a change in the ratio Red/Blue of the order of 9%. The actual variation observed of over 100% is of a magnitude that leaves no doubt of its being due to some other cause.

PLATE XVI

INTENSITY PATCHES, ECLIPSE OF THE MOON, NOVEMBER 27, 1928

A reproduction of one of the plates taken as the moon was coming out of the umbra. The rectangular patches show the varying intensities of moonlight after passing through the different filters: (1) no filter, (2) blue filter, (3) green filter, (4) red filter, (5) dark red filter. The lowest row represents the first exposure, taken at 4.54 a.m., when the moon was almost within the umbra. The first seven exposures are of 20 sec. each, and show the increase of intensity of moonlight as the moon leaves the umbra. It will be noticed that while at first the light through the blue and red filters is almost of the same intensity, at the seventh exposure the red is much stronger. The spots of varying intensity at the edge of the plate are the sensitometer patches.

Journal of the Royal Astronomical Society of Canada, 1929.

A few words must be said about the light of the moon when totally eclipsed. Most of the exposures were too faint to be measured on the photometer. On four of these, however, the red patch could be distinctly seen while there was not the slightest trace of the blue. This clearly indicates the preponderance of red light at total eclipse. The intensity of the red light at 4.25 a.m., as derived from a 9-minute exposure, was .003 on our intensity scale, and the ratio of red light to total light was .3 as against a ratio .1 at 4.50 a.m.

In summary we may say that though the results are of a qualitative nature, they seem to definitely indicate the following facts:—

1. As the moon passes into the umbra there is a marked increase in the proportion of blue light to that of red.
2. At some undetermined point this gives place to an increase in the proportion of red light which is definitely predominant at total eclipse.

It would seem that there is a proportionately greater intensity of light of shorter wavelengths in the earth's shadow just at the edge of the umbra. Undoubtedly the observed values will vary greatly, depending upon the atmospheric condition at the sunrise and sunset limbs during the time of the eclipse, but it is an interesting field for future work of a more exact nature.

In conclusion I wish to express my thanks to Dr. R. K. Young for assistance in making the observations, and advice throughout the investigation.

University of Toronto,
April 13, 1929.

THE RELATIVITY DEFLECTION OF LIGHT*

By ROBERT J. TRUMPLER

In his fundamental publication, *Die Grundlagen der allgemeinen Relativtätstheorie*,[1] Einstein derives a value of 1.7 for the deflection of a light ray coming from a distant star, passing the Sun's edge, and observed from another celestial body (e.g. the Earth). The method by which this conclusion is reached is briefly, but clearly, outlined in Einstein's original paper, and the problem is also treated in numerous textbooks on Relativity. Nevertheless Professor Charles Lane Poor[2] claims that the light deflection calculated according to Einstein's method amounts to only 1.1. It is perhaps not out of place here to give the calculation of the deflection of a light ray in full detail, in order to remove any doubt as to the correct value of the result.

According to Einstein's Theory the so-called force of gravitation is only an apparent force, introduced by our method of measuring space and time with a rectangular co-ordinate system of Euclidian geometrical properties, while in reality the space-time continuum in the Sun's gravitational field follows non-Euclidian laws of geometry or is "curved." For every point of the space-time continuum we have to define its own local measuring system adapted to the geometrical laws there prevailing. If we consider a particle freely moving in the Sun's gravitational field and describe its motion in terms of these varying local co-ordinates, the particle seems to follow its "natural path" (a geodesic), and no influence of a force is apparent. In a similar way the speed of a light wave measured in these local co-ordinates is a constant, and it is convenient to use the measuring units of time and length so that this constant is equal to 1. We shall thus measure time in seconds, distances in light-seconds (i.e. units of 186,000 miles). For an observer, who is not using local measure, but describes the universe in a Euclidian co-ordinate system, the velocity of light must then appear variable.

*Reprinted from the *Publications* of the Astronomical Society of the Pacific, by permission of the author and the editors.

[1] *An. der Physik*, *49*, 769, 1916.

[2] *Jour. R.A.S.C.*, *21*, 225, 1927.

What the observer is thus doing is to make a projection of the non-Euclidian (curved) space-time continuum, which he cannot visualize, into a Euclidian co-ordinate system, to which he is accustomed. This is quite analogous to making a chart of the curved surface of the Earth on a plain sheet of paper. The propagation of the light waves through the Sun's gravitational field can then be worked out in the projection in a similar way as we could construct on a chart of the Earth the progress of a large water wave over the ocean.

Of course such a projection cannot be made without distortion; equal intervals of space or time will not always correspond to equal intervals in the projection, and equal velocities in the original will in general be represented by variable velocities in the projection. Our projection has the peculiarity that it is identical with the original at great distances from the Sun, where the curvature of the space-time continuum becomes negligible. The two end points of the light path which we wish to study, the star and the Earth, are both sufficiently distant from the Sun that for practical purposes the initial and end direction of the light ray are the same in the projection as in the original. The distortion of the projection will make itself felt only in the neighbourhood of the Sun, through which we have to trace the light waves.

In order to construct successive wavefronts we have to know how the speed of light varies in the projection. Since the speed of light is constant in local measure of the original, we have for this purpose only to find the relationship between the time and distance measures in the observer's projection and the local time and space measures of the original, and Einstein's law of gravitation will furnish this relation.

For reasons of symmetry it is evident that the path of a light ray from a star to the Earth must lie in a plane passing through the Sun's centre. Confining ourselves to this plane, each event is defined by two space co-ordinates; the polar co-ordinates r and ϕ counted from the Sun as origin, and the time t. Einstein's law of gravitation is then given by the formula

$$(1) \qquad ds^2 = -\gamma^{-1}dr^2 - r^2d\phi^2 + \gamma dt^2 \qquad \gamma = 1 - \frac{2m}{r}$$

It expresses the interval ds between two neighbouring events in

terms of the co-ordinate changes and thus defines the non-Euclidian geometry of the local co-ordinate system. m is the Sun's mass and amounts in relativity units to 0.491×10^{-5} light-seconds; $\frac{m}{r}$ is therefore a small quantity, its maximum value at the Sun's surface is 0.212×10^{-5}, and we shall in the following always neglect terms of the order of $\left(\frac{m}{r}\right)^2$ which are far too small to be accessible to observation.

In the observer's projection Euclidian geometry is valid and for an interval ds we have the formula

$$(1') \qquad ds^2 = -dr^2 - r^2 d\phi^2 + dt^2$$

A comparison of (1) and (1') gives for every point the deformation introduced by the projection. The latter is twofold: it affects the time measure as well as the measure of radial distances:

$$\sqrt{\gamma}\,dt = dt_0, \quad \frac{1}{\sqrt{\gamma}}\,dr = dr_0$$

Since $\sqrt{\gamma}$ is slightly smaller than 1, approximately $1-\frac{m}{r}$, the local time-measure of the original is slower than that of the observer (projection); $1-\frac{m}{r}$ seconds of local time correspond to 1 second of the observer. If radial distances are measured, one unit of local measure corresponds to $1-\frac{m}{r}$ units of the observer; the local system measures radial distances in smaller units than the observer. Distances measured in the direction perpendicular to the radius vector ($rd\phi$) are the same in the projection as in the original.

Keeping in mind that the velocity of light is constant ($=1$) in units of local measure, we can now find what its amount will be in the projection of the observer. For a light ray in the direction PB (Fig. 1), perpendicular to the radius vector SP, only the difference in the time measure has to be taken into account, and the velocity of light in the projection is therefore $1-\frac{m}{r}$. A light ray in the radial direction PA is affected

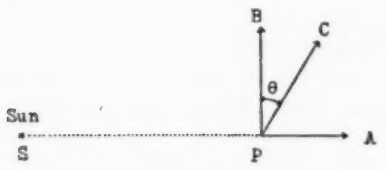

FIG. 1

by the change in time measure as well as by the distortion of the distance measure, and in this direction the velocity of light in the projection is $1-\frac{2m}{r}$. In the observer's measuring system the velocity of light decreases as the point P approaches the Sun, but the decrease is twice as much for a radial ray as for a tangential ray, and consequently the velocity of light varies with the direction of the ray. In any arbitrary direction PC, forming with the radius vector of P the angle $90°-\theta$, the velocity of light is given by the formula

$$(2)\quad c=1-\frac{m}{r}\,(1+\sin^2\theta)$$

$$=1-\frac{m}{r}-\frac{m}{r}\sin^2\theta$$

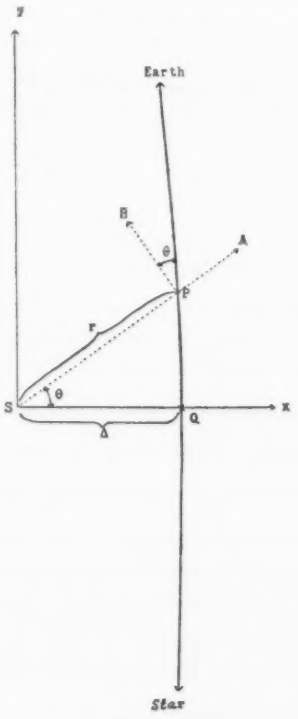

FIG. 2

According to the wave theory of light the elementary deflection of two successive wavefronts is obtained by applying Huyghens' principle. This states that the angular change dB in the direction of the wavefront is proportional to the change of the velocity of light along the wavefront: For any point P on a light ray from a star to the Earth passing close to the Sun S as illustrated in Figure 2 we have then, taking in first approximation the wavefronts all parallel to the x-axis:

$$dB = \frac{\partial c}{\partial x} dy. \tag{3}$$

It should be mentioned that this formula is not rigorously applicable to a case in which the speed of light varies at the same point with the direction. The elementary wavefront an infinitely short time after its emission will then be not a circle, but an elongated figure resembling an ellipse. From a given wavefront VW (Fig. 3) we have to construct the next following one $V'W'$ as the envelope of the elementary wavefronts of all points of VW, and

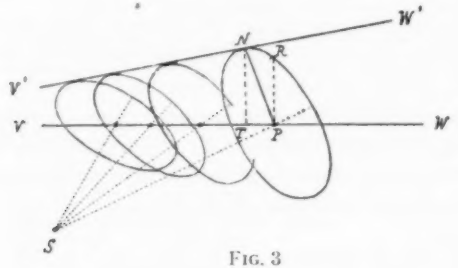

FIG. 3

the light ray PN is not exactly perpendicular to the wavefront. In formula (3) we are using PR (the velocity of light in the direction perpendicular to the wavefront) as distance between two successive wavefronts instead of TN. Since $\frac{m}{r}$ is small, the elementary wavefronts, in our case, differ little from circles, and the difference between PR and TN is found to be of the order of $\frac{m^2}{r^2}$, therefore negligible. We make then no appreciable error by computing the deflection dB of the wavefront from formula (3) provided we use for c the velocity of light in the direction perpendicular to the wavefront (PR). Both r and θ thus vary along the wavefront, and the differentiation $\frac{\partial c}{\partial x}$ has to be performed in the following way:

$$\frac{\partial c}{\partial x} = \frac{\partial c}{\partial r}\frac{\partial r}{\partial x} + \frac{\partial c}{\partial \theta}\frac{\partial \theta}{\partial x}$$

$\frac{\partial r}{\partial x}$ and $\frac{\partial \theta}{\partial x}$ are found by differentiating:

$$r^2 = x^2 + y^2,\ r\frac{\partial r}{\partial x} = x,\ \frac{\partial r}{\partial x} = \cos\theta$$

$$\tan\theta = \frac{y}{x},\ \sec^2\theta\frac{\partial \theta}{\partial x} = -\frac{y}{x^2},\ \frac{\partial \theta}{\partial x} = -\frac{\sin\theta}{r}.$$

$\frac{\partial c}{\partial r}$ and $\frac{\partial c}{\partial \theta}$ are obtained by differentiating formula (2). Our equation (3) thus becomes:

$$dB = \frac{m}{r^2}\cos\theta\, dy + \frac{3m}{r^2}\sin^2\theta\cos\theta\, dy.$$

As the path of the light ray deviates very little from a straight line, we can substitute with sufficient accuracy in all terms containing the small factor $\frac{m}{r^2}$:

$$r = \frac{\Delta}{\cos\theta},\ y = \Delta\tan\theta,\ dy = \frac{\Delta}{\cos^2\theta}\, d\theta$$

where Δ is the shortest distance between the light ray and the Sun's centre (see Fig. 2). This gives

$$(4) \qquad dB = \frac{m}{\Delta}\cos d\theta\,\theta + \frac{3m}{\Delta}\sin^2\theta\cos\theta\, d\theta$$

The deflection of the wavefront on the way from Q to P is then obtained by integrating the differential deflections over this part of the path:

$$(5) \qquad B = \int_0^{\theta} dB = \frac{m}{\Delta}\sin\theta + \frac{m}{\Delta}\sin^3\theta$$

It appears from this formula that the deflection of a light ray is made up of two terms. The first of these represents the effect of the coefficient of dt^2 in formula (1), the distortion in the time-measure or the slowing up of the local clock in the neighbourhood of the Sun. For planetary velocities which are of the order of 30–50 km per second, dt (in seconds) is about 6,000 to 10,000 times larger than dr (in light-seconds) for two neighbouring events. The coefficient γ in the term γdt^2 of formula (1) therefore produces a far greater effect than the factor γ^{-1} in the term $\gamma^{-1}dr^2$. In fact the

latter term is negligible for most planetary motions and the term γdt^2 alone accounts for their main features; it may thus be taken as the equivalent of Newton's law of gravitation.

In stating his principle of equivalence in 1911[3] Einstein took account only of the time distortion, and his first prediction of the light deflection made at that time included only the first term of formula (5).

$$B_1 = \frac{m}{\Delta} \sin \theta$$

The light path defined by this formula is a hyperbola, and the total bending of the light ray is obtained by moving the point P to infinity, $\theta = \frac{\pi}{2}$, taking into account that the bending from Q to infinity (the Earth) is the same as from infinity (the star) to Q:

$$B_1 = \frac{2m}{\Delta}$$

With the astronomical constants adopted by the *American Ephemeris* we find for the Sun's mass in relativity units

$$m = 0.4913 \times 10^{-5}$$

For a light ray just grazing the Sun's surface Δ is equal to the Sun's semidiameter (2.317 light-seconds), and in this case

$$B_1 = 0''.874.$$

The first term of formula (5) taken alone defines a light path which in first approximation is identical wtih the hyperbolic orbit of a particle moving with the speed of light according to Newton's law (Newtonian half-effect) as it was calculated by Soldner in 1801 (corrected for erroneous factor 2).[4] There is the difference, however, that the light corpuscle of Newton's Theory is increasing its speed as it approaches the Sun, while according to the principle of equivalence the light wave is slowed up.

The second term of formula (5) is due to the term $\gamma^{-1} dr^2$ in formula (1), i.e. to the distortion of the radial distance measure, or the space curvature in the neighbourhood of the Sun. The latter is responsible for the main numerical differences between

[3] *An. der Physik, 35*, 898, 1911.

[4] *Publ. A.S.P., 35*, 185, 1923; *Science, 58*, 161, 1923.

Newton's and Einstein's theories which are mostly small, but become sensible for the great speed of light. The second part of the light deflection

$$B_2 = \frac{m}{\Delta} \sin^3 \theta$$

defines a path which is no longer a hyperbola and has in general a different value than the first (B_1). Only for $\theta = \pm \pi/2$, i.e., for a light ray running from Q to infinity, the second term becomes equal to the first as $\sin^3 \pi/2 = \sin \pi/2 = 1$.

The total deflection of a light ray according to the Generalized Theory of Relativity can thus be represented as the sum of two terms, the one being the effect of the "time curvature," the other the effect of the "space curvature" of the space-time continuum. For a light ray running from infinity to infinity the two terms become equal and the total deflection is

$$B = B_1 + B_2 = \frac{4m}{\Delta} \tag{6}$$

If the light ray grazes the Sun's surface the deflection amounts to

$$B = 1''.748.$$

Professor Poor,[5] who claims that this deflection is $1''.1$, uses the same expression (2) for the velocity of light and the same formula (3) for calculating the deflection of the light ray. It is evident from his text as well as his result that in differentiating $\frac{\partial c}{\partial x}$ Professor Poor erroneously omitted the term $\frac{\partial c}{\partial \theta} \frac{\partial \theta}{\partial x}$, which we have shown above to be necessary for a correct application of Huyghens' principle.

The statement that Einstein's Theory leads to twice as large deflections as the assumption that light is subject to the Newtonian gravitation is limited to the total deflection from infinity to infinity; it does not hold for all parts of the light path, the latter being a different kind of curve in the two cases. There is no question of introducing a factor 2. To illustrate this the following Table 1

[5] *Jour. R.A.S.C.*, *21*, 225, 1927.

gives for a light ray grazing the Sun's surface the deflection along the path QP or the angle between the direction of the light ray at P and that at Q. The result of the second column is computed according to Newton's law of gravitation and the corpuscular theory of light, that of the third column according to Einstein's Generalized Theory of Relativity. The fourth column gives the ratio of the results of the two theories. The distances PQ (first column) are expressed in solar semidiameters.

TABLE 1

PQ	Newton B_1	Einstein $B_1 + B_2$	Ratio
0	0″.000	0″.000	1.0
0.2	.086	.089	1.03
0.5	.195	.234	1.20
1	.309	.463	1.50
2	.391	.705	1.79
5	.428	.840	1.96
∞	0.437	0.874	2.00

Near the point Q the light path is very nearly the same for the two theories. Most of the bending of the light ray is accomplished in the immediate neighbourhood of the Sun; beyond a distance of 5 solar radii from the Sun's centre the light ray is practically straight. Only the total deflection of the light ray, or the angle between the asymptotes, is therefore accessible to actual observation, and the fact that the light path is a differenct curve in the two theories is of purely theoretical interest.

It has been a puzzle to many astronomers why the deflection of light rays as observed at solar eclipses should, according to Einstein's Theory, be exactly twice as much as would result from Newton's Theory. The present treatment of the problem, with its perhaps somewhat artificial separation of the two terms, makes it clear that this doubling is due to a coincidence of three features:

1. That in Einstein's law of gravitation (1) the same factor γ with which dt^2 is multiplied also occurs in the denominator of the term with dr^2, or that the distortion of the radial-length measure

is of the same amount as the distortion of the time-measure.

2. That in relativity units the distance travelled by light is equal to the time elapsed, so that for a light ray the "space curvature" is of equal importance with the "time curvature," while for ordinary velocities the former is generally negligible.

3. That for $\theta = \pm \frac{\pi}{2}$: $\sin^3 \theta$ has the same value ($\pm$ 1) as $\sin \theta$.

As the observer points his telescope in the direction ES' (Fig. 4) in which the light ray reaches the Earth, the star appears to him in the direction S′. The true position of the star, however, is in the direction S, where it is seen at other seasons of the year, when the Sun is not situated in the same part of the sky as the star. The total bending of the light rays due to the Sun's gravitational field is thus observable at total solar eclipses. Its effect is that stars seen in the immediate surroundings of the eclipsed Sun appear slightly displaced from their normal positions in the direction away from the Sun's centre.

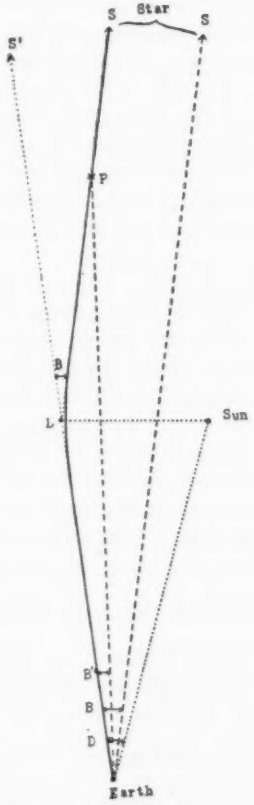

FIG. 4

On account of the great brightness of the inner corona, it is not possible to observe any stars at the very limb of the Sun, for which the light rays are grazing the Sun's surface. The stars actually observable are situated at a certain distance from the Sun, and their apparent displacements are given by formula (7) which follows immediately from (6):

$$B = \frac{1''.748}{\Delta} = 1''.748 \frac{\sin R}{\sin D} \tag{7}$$

where Δ is the shortest distance between the light ray and the

Sun's centre expressed in semidiameters of the Sun, while D is the star's angular distance from the Sun's centre and R the apparent angular semidiameter of the Sun. As long as D is small, its sine can be replaced by the angle, and the star displacements due to light deflection are then inversely proportional to the star's angular distance from the Sun's centre.

The observations made at the total solar eclipse[6] of September 21, 1922, confirm this law of inverse proportionality as well as the numerical coefficient of formula (7). No other theory is at present able to account for the numerical values of the observed star displacements. The assumption that there is an actual curvature of space in the immediate surroundings of the Sun, which is implied in Einstein's Theory, seems indeed to furnish the only satisfactory explanation why the observed light deflections are twice as large as those predicted on the basis of Newton's Theory.

It should be mentioned that the apparent displacements given by formula (7) apply only to stars for which the distance from the Sun is practically infinite as compared with the distance from the Earth to the Sun. For a planet (P, Fig. 4) seen near upper conjunction, only a fraction of the bending of the light ray is observable as a displacement in position. From the triangle ELP it follows that $\sin B' = \frac{PL}{PE} \sin B$.

Since B and B' are both small angles, we can replace the sine by the angle and substitute for PL the distance r of the planet from the Sun, while PE is the distance ρ from the planet to the Earth. We have thus approximately $B' = \frac{r}{\rho} B$. This gives for the larger planets the following displacements B' when seen at upper conjunction at the Sun's limb.

Mercury $B'=$	0".49	*Jupiter*	1.47
Venus	0.74	*Saturn*	1.58
Mars	1.05	*Uranus*	1.66
		Neptune	1.69

The bending of the light rays in the Sun's gravitational field also has the effect that the diameter of the Sun appears too large by 0".011, an amount practically negligible.

LICK OBSERVATORY, MOUNT HAMILTON, CALIFORNIA
December, 1928

[6] *Lick Obs. Bull. 13*, 130, 1928.

PAPERS PREPARED FOR THE D.A.O. CLUB

The Galactic Centre

Seminar No. 102

The aim kept in view in the presentation of this subject was to give a rough outline of the modern views held concerning the form and dimensions of our galactic universe and how we have been led to adopt such views. The extensive programme planned by Harvard on the galactic centre was outlined and some preliminary results quoted.

The Herschel star counts brought out two main characteristics of the stars: (1) The number increases very rapidly as we pass to the fainter magnitudes. (2) The stars tend to crowd towards the plane of the Milky Way. To these has been added a third feature, during the past ten years or so, that this crowding is more pronounced in the case of the fainter stars.

While the numbers are fairly symmetrical north and south of the galactic plane, a marked asymmetry is shown in the longitudes. In all latitudes more stars are seen in the approximate direction, galactic longitude 325°, than in the opposite direction. This would be explainable if our solar system were situated to one side of the centre. From the mean distances of the globular clusters, Shapley in 1917 deduced the distance to this common centre, which distance, as later revised, is about 60,000 light years. The "local system" and "Kapteyn's universe" of 47,000 million stars were touched upon.

Of recent years the idea of our universe being similar to a spiral nebula has again been much to the fore. Certain asymmetries of motion in groups of stars were easily explained if, following Lindblad, we conceived our greater galactic system to be composed of subsystems in revolution about the common axis. The observational evidence of Oort, Plaskett and others tending to confirm this galactic rotation was touched upon.

Shapley has planned an extensive programme on the galactic dimensions and structure and intends to use all kinds of variable stars to the end of securing distances. The photographic work was commenced five years ago and the programme will probably last

another ten or fifteen years, for the aim is to secure complete information of all variables found in 240 selected star fields.

In one region near to the galactic centre a star cloud was found exceptionally rich in variable stars and from the data secured this cloud is at a distance of 47,000 light years.

W. E. HARPER.

PHOTOGRAPHY OF THE PLANETS

Seminar Talk No. 100.

Until comparatively recently our knowledge of the planets was due mainly to visual observations, though Slipher at the Lowell Observatory secured some really excellent photographs of the surface markings of Mars as early as 1905. Visual observations have the advantage that they are less affected by atmospheric disturbances and the effective resolving power for fine detail is greater than can be obtained in the best photographs. A photograph on the other hand provides a permanent record of the aspect of the planet at a particular instant. In addition to this the use of various colour filters in conjunction with the photographic plate affords a new and powerful method for studying planetary atmospheres. The first work done on the photography of the planets in light of different colours was done by Wood at Mt. Wilson in 1916. More recent work along this line has been done by Wright and Trumpler at the Lick Observatory and by Ross at Mt. Wilson.

The effectiveness of the use of colour filters in photographic studies of the planets depends on the fact that planetary atmospheres show different degrees of transparency to light of different wave lengths. Thus ultra-violet light probably does not penetrate much beyond the upper levels of an atmosphere while infra-red light is more readily transmitted and may penetrate to the solid surface of the planet.

Photographs of Mars taken in light of different colours have revealed the following points of interest. The ultra-violet photographs show certain impermanent, cloudlike configurations that are invisible in infra-red light. These impermanent configurations are observed to form anew and to assume similar forms each day. They

are probably confined to the upper levels of the atmosphere and are considered to be distinct from aqueous clouds. Another feature of the ultra-violet photographs is the appearance of conspicuous cloudlike formations or haloes in the vicinity of the polar caps. The disc of the planet when photographed in ultra-violet light is clear and distinct and shows little indication of edge fading.

Photographs taken with infra-red light in contradistinction to the ultra-violet photographs bring up into strong contrast the permanent markings of the planet, which are believed to be features of the solid surface. The conspicuous, cloudlike formations observed over the polar caps in ultra-violet light are no longer visible and it is possible to observe the actual polar caps and to determine that the south polar cap is eccentrically located and shows seasonal changes in size and form. Regarding the canals and oases the photographs confirm their existence, but their regularity in design is not considered to be sufficiently well marked to support the hypothesis that they are artificial. Certain impermanent bright spots or markings may be observed and these have been interpreted as being due to aqueous clouds. The disc of the planet as photographed in infra-red light exhibits the phenomenon of edge fading and the measured diameter is smaller than when photographed with ultra-violet light. The difference in diameter of infra-red and ultra-violet images affords a means of estimating the effective height of the atmosphere which is set at approximately 50 miles. Certain dark areas on the planet are recorded in infra-red light. These areas appear green when observed visually, exhibit seasonal changes and are believed to be due to vegetation. Wright is inclined to believe, as a result of his photographic work, that the atmosphere of Mars is less clear than the pure air of the earth and that the Martian sky may be green rather than blue.

Photographs of Venus taken with light of different colours are somewhat disappointing. Contrary to the results obtained from Mars the infra-red photographs show little or no detail, and this is taken to indicate that the atmosphere of Venus is not transparent to light of this wave length. As a consequence, nothing is known concerning the solid surface of the planet. The photographs taken

with ultra-violet light show certain banded effects at right angles to the assumed axis of rotation and this is believed to indicate a more rapid rate of rotation for the planet than was formerly supposed to be the case. From various lines of evidence Ross suggests a period of the order of 30 days. As in the case of Mars, the infra-red images are smaller than the ultra-violet and exhibit the phenomenon of edge fading.

Photographs taken of Jupiter have been productive of results similar to those obtained for Venus. The infra-red images are smaller than those obtained with ultra-violet light and show edge fading. Other marked differences are shown in photographs taken with different coloured light, but none of the photographs apparently has reached the solid surface of the planet. The planets Venus and Jupiter have thus been shown to possess atmospheres with absorbing power very much greater than that of the earth. Conditions on the actual surface of these planets are still a matter of pure speculation.

References—R. W. Wood, *Ap. J. 43*, 317, 1916; W. H. Wright, *L.O.B.* 389; R. J. Trumpler, *L.O.B.* 387; F. E. Ross *Ap. J. 64*, 243, 1926.

C. S. Beals

MEASUREMENTS OF PLANETARY AND STELLAR RADIATION*

By W. E. Harper

In recent years a considerable amount of effort is being directed to the detection and measurement of thermal radiation from the planets and the brighter stars. One is apt to fall into the error of thinking that such investigations are all of very recent date and so it is well to give the historical background. The most satisfactory method of measuring small changes of temperature is by the use of thermo-electric appliances. In these the light from the source under investigation falls on a blackened receiver of very small dimensions attached to the junction of two metal strips, like bismuth and antimony, when a feeble current is set up which can be measured by a sensitive galvanometer.

*Summary of Seminary Talks Nos. 108 and 113.

As early as 1868 Huggins, by the use of such a thermocouple at the focus of an 8-inch refractor, was able to record positive deflections for Sirius, Pollux, Regulus and Arcturus. In the following year Stone, using a larger refractor verified these deflections with the further interesting result that the infra-red radiations from Arcturus were fifty per cent. greater than from Vega. Both these results were challenged by Boys in 1890 who with a radiomicrometer, supposedly much more sensitive, found no such deflections. But Nichols of Dartmouth College developed an extremely sensitive radiometer of the compensating torsion type in which a pair of small receivers were suspended from a fine quartz fibre. Using this at the Yerkes Observatory in the summers of 1898 and 1900 in connection with the 24-inch reflector, he found that Arcturus gave more than twice as much heat as Vega and Jupiter nearly five times as much. About this time, too, Angström developed his pyrheliometer to measure the outgoing radiation from the earth at night. In a brief test at the Allegheny Observatory, Pfund of Johns Hopkins University also obtained deflections from a few bright stars.

For the past twenty years Coblentz at the Bureau of Standards, Washington, has been interested in the subject and has issued a large number of papers dealing with his investigations. Considerable time has been spent in establishing standard lamps and candles and in testing the thermo-electric qualities of various metals and their alloys. Among other metals that have been used are antimony, bismuth, copper, gold, platinum and tin. Several combinations of these and their alloys are satisfactory, one of bismuth and an alloy of bismuth and tin being frequently used. Low heat capacity and low heat conductivity obtained by diminishing the size of the receiver and connecting wires are of equal importance in securing maximum sensitivity. Receivers as small as 0.1 mm. diameter, painted dead black, were finally in use.

But the sensitiveness of such a thermocouple is vastly increased by placing it in a vacuum. From atmospheric pressure down to a pressure of 1 mm. the sensitivity remains about constant, but further decreasing the pressure results in a greatly increased efficiency. Methods of maintaining such low pressures by the use of calcium chloride are described.

In the summer of 1914 Coblentz tested out various thermocouples on the stars, using the Crossley reflector at the Lick Observatory. The sensitive thermocouple was placed in a vacuum chamber and the image of the star was made to fall on the receiver after passing through a window of fluorite. The resulting current set up was recorded by a galvanometer and the mean difference of a number of readings with the image 'on' and 'off' the receiver was taken. As the receiver sums up the radiations of all wave-lengths incident upon it the *total* radiation was thus obtained for each of 110 of the brighter stars.

But it was felt far more important to obtain the radiation coming from definite regions of the spectrum than to measure the total radiation and for this purpose various screens were introduced in the path of the star's light. The transmission of these various screens for the different wave-lengths being known, the fraction of each kind of radiation to the total radiation could be derived by the corresponding galvanometer deflections. Violet light is of wave length 0.4μ; red light 0.7μ; but the great bulk of the planetary radiation comes in waves in the infra-red region whose lengths are 8.0μ to 14.0μ. A water cell 1 cm. thick will transmit radiations from 0.3μ to 1.4μ but cuts out entirely all those of greater wave-length; fluorite cuts out everything of longer wave-length than 11.0μ while rock salt is one of the best transmitters of these long wave-length radiations letting, through even 70 or 80 per cent. at 18.0μ. By using these screens singly or in combination the amounts of each kind, or the percentage composition of the various radiations could be determined.

His results showed that higher percentages of infra-red radiation, as compared with the total, came from the 'later' type stars. In other words if two stars, an A-type and an M-type, were of the same apparent brightness the galvanometer deflection would be much greater in the case of the latter. By taking account of the stars in each type down to apparent magnitude 6.25 he was led to conclude that the total radiation of all these stars falling on 1 sq. cm. of the earth's surface would require from 100 to 200 years in order to raise the temperature of 1 gram of water 1°C. Hence in measurements of nocturnal radiation the correction for incoming stellar radiation is negligible.

Seven years later, after making many improvements, he went to the Lowell Observatory and there determined the spectral distribution in this way of 16 stars. Comparing this distribution with that of a black body he was led to deduce temperatures for the stars, of which we may mention Betelgeuse 3000°, Polaris 6000°, Vega 8000° and Rigel 10,000°.

In the following year, 1922, he verified these temperatures and made a start at obtaining planetary temperatures. It was found that the planetary radiation increased as the density of the surrounding atmosphere decreased. Thus from Jupiter with an extensive atmosphere, there is none; whilst 80 per cent. of the total radiation from the moon, where there is no atmosphere at all, is of this character.

Two years later, during the opposition of Mars in 1924, he again investigated the radiation coming from all parts of the planet, and in four separate ways arrived at a noon-day temperature of Mars from 10° to 20°C. The average temperature for the whole disk was placed at −28° C.

His 1926 observations in collaboration with Lampland were along the same lines as those of 1924 and the results seem to corroborate those previously obtained.

As the effectiveness of the thermocouple increases with the amount of light that can be converged upon the receiver it is not surprising that the 100-inch telescope was brought to bear upon this problem. Refractors, of course, are of no use, as the radiations under consideration would be totally absorbed by the object glass. The equipment needed is a reflector to collect the radiation, a vacuum thermocouple to change that radiation into electrical energy and a galvanometer to register the current, preferably by some photographic device. Pettit and Nicholson have given us their results in a paper appearing in the November, 1928, issue of the *Astrophysical Journal*. They were quite successful in making sensitive thermo couples, the total weight of one being approximately only 1/1000 that of a drop of water. This was attached at the Newtonian focus, and by bringing the star image first on one junction of the couple and then on the other deflections of double amplitude were secured.

Their results are stated in terms of an A0 star of apparent

magnitude sufficient to produce the observed result. Certain corrections are made to their observed readings to reduce them to standard conditions. Thus there is a correction for zenith distance, for the age of the silver coat on the mirror and for absorption by windows other than those of rock salt. They list results for 124 stars arranged by types. As with former investigators they find the later types give increased infra-red radiation and moreover giants have more of it than dwarfs. By comparing the star's spectral distribution of radiation with that of a black body they derive temperatures for the various classes in fair agreement with other determinations. Ten long-period variables, observed over a period of 5 years, show that these radiations synchronize in time with the light variations but are of much lesser range, averaging 0.9 magnitude radiometrically but 5.3 magnitudes visually.

REVIEW OF PUBLICATIONS

La Physique de la Gravitation et la Dynamique de l'Universe, par Thomas Tommasina. 302 pages. 6½ x 10 inches. Paris: Gauthier-Villars, 1928, price 50 fr.

This work, by the Swiss physicist Tommasina, is "based upon the discovery of the real mechanism of radiations, showing their reciprocal gravitational function", and is considered by its author as his "scientific testament". It deals with the foundations of physics and mechanics and requires close reading. The present writer cannot offer a critical judgment of it, and will simply give the printed statement of its aim.

The author presents the work as a *vade-mecum* for daily use by young workers in physical laboratories and astronomical observatories, and for the physicists and astronomers who direct them. The aim of the work is to provide a sure guide, precise and clear, rendering easy the exact interpretation of the real nature, purely mechanical and material, of all the phenomena of the fields of physics and astronomy, as also of the agents which produce them.

The author is convinced that his work comes at the right time, as it will furnish the practical information necessary to rescue theoretical and experimental physics, astrophysics and celestial mechanics from the critical state in which serious students have recognized it to be for many years.

Chapters I and II are introductory; chapter III deals with the physics of universal gravitation; chapter IV discusses two precursors of the relativists—Poincaré and Lambert; chapter V is devoted to Einstein and his two relativity theories and his erroneous interpretation of physical phenomena.

To those scientists and philosophers who are exploring the fundamental concepts of science this book will be found useful.

C.A.C.

NEWS AND COMMENTS

In April 1926, Professor A. Wolfer, having reached the age limit, resigned as Director of the Zurich Observatory, and was succeeded by Professor W. Brunner. The computation of the Wolfer Relative Sunspot Numbers, based on the Zurich observations supplemented by those of other observatories throughout the world, has been eagerly awaited from year to year. In Publication CXIX, Professor Brunner has recently given the relative number for 1928 as 77.8. Since the minimum (1923.6) they are: 1923, 5.8; 1924, 16.7; 1925, 44.3; 1926, 63.9; 1927, 69.0; and 1928, 77.8.

Mr. E. A. Hodgson, seismologist of the Dominion Observatory, attended the meetings of the American Geophysical Union held at Washington, April 25-26. He presented a paper on the Seismicity of the Arctic, discussing the regions, Iceland to Siberia, the Lena River and the West coast of Banks Island. He also presented a paper by A. H. Miller of the Dominion Observatory in which the results of his recent pendulum measurements were given: Washington, 980.1170; Ottawa, 980.6214; Greenwich, 981.1885; and Potsdam, 981.2750.

Mr. Hodgson also attended, as Chairman, the meetings of the Eastern Section, Seismological Society of America, held at Fordham College, New York, April 30-May 1. He presented an abstract of his paper on "The Seismicity of the Arctic", and also a paper by Mr. C. C. Smith, Dominion Observatory, on "A Convenient Time Conversion Chart", in which are superimposed on a Mercator's projection of the World, 24 vertical columns of the hours indicating the corresponding times at different places, and by diagonal lines the change in date. (Copies of this convenient chart may be had by application to the Director, Dominion Observatory). Retiring as Chairman, Mr. Hodgson was elected Chairman of the Publications Committee.

Mr. C. C. Smith of the Dominion Observatory, Ottawa, would

be glad to have communications from any readers concerning old clocks in Canada and their mechanisms.

Mr. Ernest A. Hodgson of the Dominion Observatory is anxious to receive reports of local earthquakes, ground noises, and landslides in connection with his study of the seismic regions of Canada.

Harvard College Observatory, Announcement Card 87 of May 9, states that two cablegrams had been received from Professor Stetson at Alor Star, in Kedah, reporting that at 5.10 a.m. there were "Good Prospects" for the eclipse observations, and at 8.10 a.m., "High cirrus otherwise successful corona illumination fifteen hundredths foot candles preliminary". The first cabled reports from Siam reported cloudy weather. Fuller reports are awaited with anxiety.

REDeL.

NOTES AND QUERIES

Communications are invited, especially from amateurs. The Editor will try to secure answers to queries.

THE COMMONWEALTH SOLAR OBSERVATORY

The first publication from the new Australian observatory on Mount Stromlo, Canberra, has just been received and we are glad that this observatory which has been planned for some years, has finally materialized. The memoir is dedicated to all those who have assisted in the project, either by gifts or influence. The first number of the publications from an observatory ordinarily describes the equipment and organization, and we look forward to hearing about these matters later.

The establishing of a new observatory in the southern hemisphere is of great importance to astronomy, and we have all watched the growth of the Australian project with great interest. Sydney, Melbourne, Adelaide and Perth for years have had observatories which have made valuable contributions to the older astronomy. The new institution will engage in research in the so-called

physical astronomy and its location, in the southern hemisphere and in longitude eleven hours will place it in a strategic position to supplement observations taken in Europe or America.

The Director of the observatory is Dr. W. G. Duffield, and with him are five other astronomers, all of whom have taken part in the observations for this first memoir of the observatory which is on the light of the night sky. The observations were made as a part of the scheme originated by Lord Rayleigh and carried on, at his instigation, in various parts of the world. It is not so much, however, on the material of the memoir that we desire to report as on the acquisition of the new observatory in the southern hemisphere. We hope to hear more from it in the next few years.

Venus Observations

Have the Venus-crescent observers any idea of the extent of irradiation? How long was it after sunset? If we mentally subtract the "spikes" the remaining seeming-solid disc is still 4 to 8 times the real diameter. Or are there eyes not subject to irradiation? How much can auto-suggestion do? Can the observers give the true orientation of the crescent, being at the same time ignorant of what it ought to be?

If Venus is not observed until it is brilliant, looking through holes in a card (pin hole up to 1-16 inch) will "give her a haircut", as Galileo says. On April 14, I tried it. It seemed to me silver grey—a perfect little disc.

Right after sunset from about March 15 the form could be easily made out with a 4-power glass.—*J. Duff, Sidney, B.C., April 22, 1929.*

Appeal for Historical Researches of the Leonids and other Meteors

Reports from observers indicate that the Leonid meteors have begun again in what should be their thirty-first reappearance since A.D. 902, "the year of the stars." Of these possible reappearances known records exist of only a part. The great work of Newton, Adams and Schiaparelli, done in the 'sixties of the nineteenth cen-

tury, depended on reports of only fifteen. These were found scattered in the annals of Europe, the Hither Orient, Africa and China by Chladni and his successors, by Herrick, Charles, Perrey, E. Biot, and A. Quetelet. Quetelet summarized the history of meteor showers in successive catalogues, the last of which appeared in 1861. The Leonid records collected by Newton in the American Journal of Science for 1864 have hardly been augmented in the sixty-four years since.

It is evident that many sources of information have not been searched. Such are the records of Indian and perhaps Egyptian literature, the *Relations* of the Jesuit missionaries to Canada, other reports, civil and military, from the French possessions to the home government, and reports of all sorts from Spanish America, Brazil and the Phillipines to the Church authorities, and to the governments in Madrid and Lisbon. Probably also the logs of shipping and the records of merchants contain references to meteors, and, among them, to the Leonids. Perhaps the investigators of Mayan astronomy may be able to add to them. It is hard to believe that E. Biot's search of Chinese literature, ended eighty years ago, exhausted that vast reservoir; and the annals of Japan and Korea are equally unfinished.

It is therefore suggested that persons who have access to such records, or who are conversant with their contents, should either publish in full detail, and as soon as convenient, catalogues of ancient meteor observations, or should send copies in manuscript to persons or institutions able to make good use of them.

An understanding of the calendars involved is the only astronomical knowledge necessary for such historical research.

The dates related to Leonid showers are likely to be found about the beginning of each century, and about one-third and two-thirds through each century. For several hundred years they have come in early November, while previously they were in October, and still earlier, in September. Research may discover references to these and other well-known showers in works not now known to contain such; and others of earlier date may be found, of the Renaissance and the Middle Ages.

An appeal essentially as above has been circulated privately, and has already elicited information derived from a search of Russian chronicles, by D. Sviatsky, of Leningrad. And also a list has been received, of probable Leonid dates, unearthed by K. Hirayama, of Tokyo Observatory, from Japanese and Korean records. Of the dates in that list, eight are entirely new to occidental astronomy, and fill many gaps in the record.

It is evident that the compliance of scholars with the request for historical research in the field of shooting stars, meteors and fireballs, would be a distinct service to science.

The Harvard Observatory Library begs to be favoured with reprints, etc., of publications bearing on this topic. Send reports to Willard J. Fisher, Harvard College Observatory, Cambridge, Mass.

FOR CONSOLATION

(Written for a young girl bereaved of her father.)

Dear! go for consolation to the stars.
When Earth, in shadow, hath retired to rest!
And, when thy heart is sad, and sore oppress'd,
And soul seems cooped behind eternal bars,
Look up! great healing there for all life's scars!
Interpret starry rays, that flood the west
From boundless distances; that—radiant—jest
At hopelessness; as answer to thy quest!

And, when thy haunting fears have left thee, dear,
And all the glow of starlit skies hath gone
Deep down into thy soul, keep gazing—clear
Unto the dawn; new hope shall lead thee on!
No sorrow, burdensome, can crush thy soul,
If thou wilt let the stars thine heart control!

KILBEE GORDON.

To Mary Hallett,
Fort Vermilion,
Peace River District.

February 10th, 1929.

VISIT OR MR. W. E. HARPER TO TORONTO

On Friday evening, April 19, 1929, at Hart House, University of Toronto, the officers of the R.A.S.C. in Toronto, and some other members entertained W. E. Harper, M.A., of the Dominion Astrophysical Observatory, at Victoria, British Columbia, and President of the General Society, to an informal dinner, followed by a round table conference on the work being accomplished by the staff in that observatory.

Nineteen were present, including the guest of the evening, President Harper. Those who sat down to dinner in the Faculty dining room were Mr. Harper, Professors Chant, DeLury, Gilchrist, Young, Satterly, Beatty, Pounder and Robinson, Dr. W. M. Wunder and Messrs. J. R. Collins, J. H. Horning, W. E. W. Jackson, R. A. Gray, R. S. Duncan, H. W. Barker, F. T. Stanford, E. J. A. Kennedy, and A. R. Hassard.

The conference resolved itself into a general conversational exposition of the work carried on in Canada's greatest observatory. Work with the great 72-inch reflector was started by Dr. J. S. Plaskett and Dr. R. K. Young, and Mr. Harper migrated thither from Ottawa a year later, in 1919.

Mr. Harper stated that much anxiety was felt when the massive telescope was set in position regarding the work it was capable of performing. The great glass, having been cast in one country, prepared in another, and erected for use in a third, must have cost those who were to work with it considerable apprehension. But so finished was its excellence, and so satisfactory its performance, that after its preliminary trials, all fears were allayed, and observing has proceeded as if the instrument was as old as one of Herschel's or one of Newton's.

The original programme involved the examination of over six hundred stars for the purpose of ascertaining their radial velocities. This was done by photographing the spectra of the stars in question, followed by a systematic study of the photographs. Two years were employed in this work and the success attending its achievement was gratifying to the staff engaged. Many of the results of those months of arduous endeavour have been published at intervals in the pages of the *Journal*. Mr. Harper stated that owing to certain improvements in the instruments and in the photographic plates employed, the average time used in making a spectogram of a star has been reduced to a period of from one-half to one-quarter of the time formerly required for a similar performance when he first became attached to the observatory. To the surprise of his audience he stated that as many as twenty-four photographs of these spectra had been taken on a single evening. He jocularly supplemented this statement by adding that "an evening" such as was capable of producing this prodigious achievement would represent a December or a January night, with the work proceeding from half-past four on one afternoon until seven o'clock on the following morning.

"It meant a fifteen hour day!" remarked the speaker.

"The labour unions would not be favourable to that!" slyly interjected Mr. Barker.

After following the two years' programme, the staff of Victoria observatory diverged from their previous policy, Mr. Harper continued, and proceeded with work more of an individual nature. They still proceeded with the photographing of the spectra of stars, centering chiefly on those averaging about magnitude 6.5 and slightly fainter. Many stars listed in the Boss Catalogue, and stars of the Wolf-Rayet type, as well as those known technically of types O, B and M, have undergone careful photographic examination. Their spectra have been studied and comparisons have been made, wherever possible, with the results published by other observatories where such work has been undertaken. Many reports of this activity have been given publicity through the columns of the *Journal*.

In reply to inquiries, Mr. Harper stated that the photographs of the stellar spectra were taken at the principal focus of the great instrument when arranged as a Cassegrain telescope. In the delicate operations of taking the photographs it was always necessary here, as elsewhere, to aid the clock-driving of the telescope by manual power. The trained and tireless eye and the skilled hand of the observer supplemented the driving clock in keeping the star constantly on the slit of the spectograph. In practice a minute change of direction of the instrument, as mechanically guided, was required to be made by hand once in about every fifteen seconds. When an observer is required to spend nearly fifteen hours of a night in this trying occupation, it is evident that the demands made upon him must be of the most exacting and painstaking nature. And the movements made by hand of this supplementary nature were in no sense automatic, but followed slight unexpected movement of the star's image.

It was interesting to learn from the lips of Mr. Harper that this delicate and ceaseless correction of the telescope's movements was accomplished by utilizing a beam of light passing from the small secondary mirror, down in the same direction followed in the recording of the star's image on the plate, but deflected to the side of the instrument; thus demonstrating that the telescope might be used at the same time for the double purpose of securing a photographic image and guiding the direction of the instrument.

The surface of the great mirror, Mr. Harper stated, was once regularly silvered about two or three times a year, but more recently the intervals between applying the silver coats have been extended, and the latest silvering occurred a year ago. Silvering in the winter season he regarded as inadvisable, because the silver coating deposited in the severe weather exhibited a tendency to peel away. The extremely thin surface of the metal was observed to form small blisters on the surface of the glass. A silvering in other seasons evinced no indications of a similar tendency.

Two pounds of nitrate of silver crystals were required for producing the requisite surface of silver on the four thousand and more square inches of face of the telescope's monumental mirror. At a price of about a dollar and a quarter the ounce for these crystals, as commercially sold, and with the other necessary chemicals also, it will be seen that it costs in excess of fifty dollars to replace an old film of silver by a new one on the giant terrestrial mechanical eye of the telescope which gazes fixedly into the expansive vault of the Heavens. Should a fault occur in the application of these chemicals to the glass, and the operation rendered futile, as so often occurs when engaged in this elusive operation, that money is utterly wasted, inasmuch as there can be no satisfactory commercial salvage effected of the gallons of liquid thus employed in the futile operation.

Thirty thousand visitors per year, averaging about one hundred each day, direct their steps to this remotely situated, and most efficiently equipped observatory. There is a regular 'bus service from the City of Victoria along the eight picturesque miles leading to observatory summit reaching upward to the stars. So familiar are the drivers to this gigantic wonder of Canada,—the great telescope and its lofty home,—that if the staff of the observatory be engaged during the visits of this numerous band of pilgrims to Saanich Hill, the motorists display adequate qualifications for furnishing the strangers with the latest information regarding the marvellous speed with which stars are rushing towards our solar system, or plunging "head-on" towards our sun and its compact family of planets, rendering a collision with us so imminent that a million or more years from now we may be consumed by the titanic impact, thus filling the present generation with disturbing anxiety at the portentous proximity of the event. And it is no uncommon occurrence for chauffeurs to entertain their passengers with stories of suns that "flash a million miles a day", "runaway stars", "islands in the galaxy", "the apex of the sun's way", "dying suns", "stars of the Algol type", and the majestic processional movement of our system in the direction of the constellation Lyra, as they proceed along the winding ways which leave the clustering lights of Victoria behind, and permit the alluring approach to a theatre where tens of thousands of luminaries more lustrous than any collection of electric lights, fling their brilliant beams down through the colossal tube of the greatest to be found in British dominions. And these scientific qualifications seem to be more fitting qualifications for premiership in motor driving about the environs of British Columbia's capital city than a knowledge of the motor vehicles act, or the police regulations in regard to motor traffic.

Students, Mr. Harper said, are appointed periodically to Victoria observatory, by the Federal government, and these students come, some from England, others from the United States, and not a few from Canada. Some of these students have given rich promise of illustrious futures, and their original research work has been of the very highest excellence.

Many other topics were discussed on this occasion, notably the use of certain regular periods on "the air", in publishing abroad the discoveries in astronomy by means of the radio, and the reception of reports from the various centres of the Royal Astronomical Society, which might serve to further popularize the science, and also the further problem of supplying the press with the latest tidings which may be wrested from the orbs around us, when telescopes "feel from world to world, and charms her secret from the latest moon!"

ALBERT R. HASSARD

MEETINGS OF THE SOCIETY

AT VICTORIA

March 13—The meeting was held in Victoria College, at 8.15 p.m., President J. A. Pearce in the chair.

Two new members were elected:—

Dr. J. W. Hewett, Ocean View Road, Victoria, B.C.

Dr. Chas. Watson, Alert Bay, B.C.

Mr. A. H. Reed, Argyle Court, 424 Linden Ave., Victoria, was transferred from the Winnipeg section.

The President informed the meeting that the Victoria Centre was endeavouring to form a library for the use of its members.

The main address of the evening was delivered by Mr. R. O. Redman, M.A., a graduate of Cambridge University, and now of the Dominion Astrophysical Observatory. His subject was "Double Stars". The speaker first traced the history of Double Stars, and particularly mentioned the work of Herschel, Struve, Burnham, Innes, Hussey and Aitken. He discussed both visual and spectroscopic doubles, and the methods of measuring them, their orbits, mass, size, density, and showed how and what information could be obtained from a study of the light curves. Mr. Redman explained various theories that arise in connection with the study of binaries, particularly the mass-luminosity relation of Eddington, the age of the universe, and the theory of the formation of binaries. The lecture was well illustrated by lantern slides.

April 9—The Society met at Victoria College, at 8.15 p.m., President J. A. Pearce in the chair.

The President drew attention to the reports of the branches of the Society published in the last issue of the Journal. Mr. Harper, in a few words, explained the aims and functions of the Society.

Two new members were elected: Mr. S. H. Anderson, Hornsby Island, B.C., and Mr. Nelson Allen, 1728 Denman St., Victoria, B.C.

The speaker of the evening was Kilbee Gordon on the subject "Stellar Influences". His aim, as he pronounced it, was to "help us know the stars, to bring them nearer to us". Quoting extensively from the Bible, Lytton, Thompson, Longfellow, Southey and others, he pointed out the great influence the stars had exercised over the minds of poets. The speaker reminded us that stars in the old days were omens, and were treated as a divine compass to guide the traveller on his weary way. The speaker closed by reading one of his own sonnets, composed at Shawnigan Lake some months previous.

Dr. Plaskett moved a hearty vote of thanks.

WALTER H. GAGE,
Secretary.

AT TORONTO

March 12, 1929—A regular meeting of the Society was held in the Physics Building of the University of Toronto at 8 p.m., Mr. J. R. Collins in the chair.

The following were elected members of the Society:—Miss W. D. Woolcombe, B.A., 310 Huron St., Toronto; Miss A. W. Turner, M.A., 329 Huron St., Toron; Mrs. R. N. Johns, 86 Brock St., Oshawa, Ont.; Prof. A. J. Pyke, University of Saskatchewan, Saskatoon.

Mr. Miller noted that the barometer had been very low lately, and expected a tornado, but there was only a gale of 45 miles an hour. He noted that though Mars was in a favourable position for observation, there were no reports and spoke of the need for more observers.

After explaining the new program, Mr. Collins called upon the operator of the Eastman Kodak Company to show the coloured pictures kindly lent by them. Their beauty was much appreciated.

Mr. R. S. Duncan spoke of the work done by the Lunar Section of the Society in its early days, and thought that the study of the Moon was being neglected by the Society. Slides were then shown of the surface of the Moon, and Mr. Duncan named many of the prominent ring-plains, craters and mountains, and spoke of the theories put forward to explain their formation.

March 26—The regular fortnightly meeting was held in the Physics Building of the University of Toronto, Mr. J. R. Collins in the chair.

A letter of appreciation of the Socieyt's publications was read from the Rev. J. T. W. Claridge, Leicester, England.

The speaker for the evening was Lieut. J. H. Horning, M.A., on the subject, "Under the Northern Cross with Allenby in Palestine". In a splendid address Lieut. Horning recalled the hectic, trying days of the Great War. He outlined the campaign against the Turks by the Allies, from the commencement to the final triumph in the occupation of Jerusalem. In a won-

derful series of slides which the lecturer had prepared from photos taken by himself, he gave the audience an insight of the difficulties which faced Allenby in his advance over the desert; no water for man or beast, blinding dust storms, intense heat,—all these had to be surmounted. A striking illustration of the importance and size of the operations in this theatre of war was given by the fact that 75,000 Turks were taken prisoners in one day and hundreds of guns captured.

The thanks of the meeting were tendered by Dr. Chant and others, who spoke in generous terms of Lieut. Horning's splendid war record.

April 9—The regular meeting of the Royal Astronomical Society of Canada was held in the Physics Building of the University of Toronto, at 8 p.m., Mr. J. R. Collins in the chair.

The following were elected to membership in the Society:—Mr. M. S. Groh, 33½ Thorncliffe Ave., Toronto; Miss Edith M. Lines, Warwick West, Bermuda, Life Member; Mr. Wm. E. C. Miller, Innisfree, Alberta.

Mr. A. F. Hunter drew attention to the coming eclipse of the Sun on May 9, which, however, would be invisible in Canada.

Attention of the members was drawn to the sudden death of Dr. E. T. White, of London, Ontario, who had been secretary-treasurer of London Centre since its formation.

The paper of the evening was by Professor J. C. McLennan on the subject, "More about Light". The experiments and lantern slides which Prof. McLennan used in his lecture showed the progress of the study of light in recent years, especially the last quarter of a century. The view of Newton regarding light corpuscles travelling at the enormous velocity of 186,000 miles per second was contrasted with the view of James Clerk Maxwell, who showed that waves in the ether are transmitted, no difference how long or how short, with the same velocity (186,000 miles per second). All such waves originate in some oscillatory movement. As a deduction from the Einstein view of the relations of light and matter, light is found to possess mass. The influence of the sun on light rays, seen during a total eclipse of the sun, shows this quality of light. Light is produced by some vibration within an atom of an elementary ubstance, of which there are known to be 92 kinds. Each kind gives off its own kind of vibrations. This study has led to the discovery that there are two kinds of fundamental parts of atoms, viz., electrons and protons. The atoms can be broken up into these parts, and when the positive and the negative parts unite, matter disappears. In other words, radiation can be turned into matter, and matter into radiation. Bohr showed how atoms are constituted and how to account for the origin of light, viz.—the emission of light corpuscles takes place when the vibrating electron assumes a smaller orbit than it had. The new experiments on light have been of fundamental importance in this interesting subject.

A resolution of thanks by Mr. A. F. Miller, seconded by Prof. Chant, concluded the interesting lecture by Professor McLennan, who was assisted by Mr. McLeod.

E. J. A. KENNEDY,
Secretary.

AT OTTAWA

March 1—The meeting was held in the National Museum, Mr. J. S. Lane, the Vice-President, was in the chair.

The lecture for the evening, entitled "13 Months in 1933", was delivered by the President, Mr. C. C. Smith, B.A., F.R.A.S.

Mr. Smith sketched the genesis of the calendar from the Egyptian to the Gregorian, showing that the "evil that men do" lives after them. He referred to the most conspicuous faults of our calendar, particularly those resulting from unequal months, split weeks and varying yearly dates.

A short synopsis of the history and nature of the many suggested improvements showed that these had now been reduced to two; 1st, the equal quarter calendar with each quarter divided into three months of 30, 30 and 31 days respectively; and 2nd, the Cotsworth calendar of 13 months of 28 days each. The many advantages of the latter calendar were illustrated by the lecturer and the objections to it—that the quarter and half year do not contain whole months, the bogey of Friday the 13th in every month, and the inertia of long established habits—pointed out.

Mr. Smith explained that the League of Nations has taken over from the International Board of Commerce, the handling of the matter of calendar reform, and public opinion is being tested out. He also stated that the year 1933, in which Sunday is the first day, is a convenient year in which to initiate the improved calendar if the demand for it is sufficiently insistent.

At the close of the lecture a vote of the audience showed an almost unanimous desire for the new calendar.

March 22—The meeting was held in the National Museum. The President, Mr. C. C. Smith, was in the chair.

Miss A. Vibert Douglas, Ph.D., of McGill University, gave the address of the evening. Her subject was "The Signs of the Zodiac". Miss Douglas divided her lecture into two parts, Ancient and Modern Astronomy, and illustrated her talk with many interesting and unusual slides.

Miss Douglas spoke in part as follows: Ancient Astronomers, to whom the sun was the source of life, darkness the abode of evil, and the stars the habitations of the Gods, had at a very early date mapped the sky quite definitely. They recognized the so-called fixed stars, which they grouped in somewhat fantastic ways into different constellations, as distinct and different from the "seven wanderers"—the sun, the moon and the five naked-eye planets.

They noted that in their yearly motions, sun, moon and planets kept within a certain belt of the sky. This belt, containing twelve constellations, they named the Zodiac, meaning "zone of animals", since all the constellations, excepting Libra, represented figures of living animals.

As the year progressed, the sun apparently moved eastward through these constellations. It was thus only natural that the ancients should come to identify the position of the sun in the zodiac with the seasons of the year.

Many interesting slides illustrated the symbols of these zodiacal constellations which were used by the Babylonians, Egyptians and Chinese.

These early people observed that the equinox, or point on the equator where the sun crosses it, moved slowly westward along the ecliptic each year. Hence in the course of years the equinox moved out of one constellation into the next westerly one. The rate of this motion, called the *precession* of the equinoxes, is well known, and it is due to this that we are able to determine the date of the building of the Pyramids of Egypt and the old monuments at Stonehenge.

Contrasted with ancient superstitions and astronomical practices, the lecturer explained the modern ideas of the true nature of the stars and planets, their motions and the numbers of the stars that are found in the Galaxy.

Dr. Douglas mentioned one particularly interesting and curious result of her investigation of certain stars, from spectrograms taken at the Dominion Observatory. In regions of the sky which are characterized by the presence of much nebulous matter, the giant stars show very marked evidence of having been bombarded by myriads of meteorites.

This exceedingly interesting lecture was concluded with reference to the fact that both ancient and modern astronomy vindicated the faith of the scientists that order and harmony do exist in the universe.

A hearty vote of thanks was tendered Miss Douglas for her splendid lecture.

April 12—Through the courtesy of the Director, Mr. R. Meldrum Stewart, a most successful Soirée was held at the Dominion Observatory on this date.

Through the kindness of the Observatory Staff, the various instruments were on exhibition and their uses explained.

In the Seismological Division records of the larger earthquakes obtained at Ottawa since Jan. 1st, 1929—ten in number—were exhibited, together with such noteworthy records of earlier date as the San Francisco, Kansu and Tokyo earthquakes. A series was shown illustrating the effect of instrumental damping on the records of different earthquakes, as recorded on two instruments mounted on the same pier, and with constants identical except for different degrees of damping. A second series showed the remarkably similar records of a series of earthquakes as recorded on seismo-

graphs of identical constants mounted in locations separated by 35 miles.

Folders were distributed containing samples of earthquake records and explanatory material which were used to illustrate a description (as given to a number of groups of visitors) of the regular routine followed in the case of the larger earthquake records—the press report, correlation of data from outside stations, final and routine location.

In the basement of the building, in the Solar Physics Laboratory, many interesting instruments were explained to the visitors. These included the 23-foot solar spectrograph with attachments, the solar camera and cœlostat, a small direct vision spectroscope used to view the whole spectrum and lines of lithium, sodium and magnesium.

In the office on the ground floor were the Ottawa double spectro-comparator and the Tœpfer measuring machine; the Ottawa graduated sphere, position circle and co-ordinate frame for determining heliographic positions, sunrise and sunset times, etc. Some interesting charts of various terrestrial phenomena showing relationship of sunspot variations, were on exhibit, and also several series of photographs showing (1) The march of spots across the solar disc, due to solar rotation; (2) A partial eclipse of the sun; (3) A transit of the planet Mercury across the sun's disc. Other photographs included those of small parts of the solar spectrum on a large scale, sunspot spectra, rotation spectra, comparison spectra of iron, magnesium and iodine absorption which were used to illustrate the determination of radial velocity correction, rotation and orbital motion of the earth, giving the solar distance.

The observing rooms of the meridian telescopes, where the fans keep the air at outside temperature, were not as popular as the other rooms, but the visitors could easily appreciate the discomfort experienced by the observers in cold weather. The history of time keeping, from the age of water clocks to the present, was illustrated by slides and by a number of clocks specially collected and arranged for the purpose. The many uses of wireless in time keeping and distribution were illustrated and some special experiments in electron emission were shown. All the different instruments and equipment in this division attracted much attention, as usual, the Mercedes calculator getting a large share.

The Library was also inspected by the visitors, who were particularly interested in the astronomical books, periodicals and exchanges, as well as the astronomical slides.

In the Terrestrial Magnetism Section were shown the various types of instruments used in determining the three magnetic elements—declination, inclination and horizontal intensity. Maps were on exhibit of Indian and Eskimo curios gathered on survey expeditions. The exhibit comprised articles of native workmanship which were representative of the arts and crafts of the various tribes extending from Labrador and Yukon.

A Foucault pendulum, set up in the main hallway and about 30 feet in

length, attracted much attention. This was one of the exhibits of the Gravity Section. Other instruments were also shown, including the pendulums and knife edges of the Half-Seconds Pendulum apparatus; barograph and aneroids for measuring heights of topographic zones in the vicinity of gravity stations; a five-inch Cooke transit used to obtain the position and elevation of gravity stations and important features. An interferometer for measuring the sway of the pendulum case was set up to show the interference fringes of sodium light.

Through the kindness of Dr. H. M. Ami, a collection of implements illustrating the industries of pre-historic man was exhibited and proved to be extremely interesting. Dr. Ami has, for several years, been making collections from a district in France where Canada has obtained the privilege of excavating, and through his efforts there, he has gathered a splendid collection of implements and of various relics of Neolithic, Paleolithic and Pleistocene ages. Dr. Ami and his assistant, Miss Seeley, were most kind in describing to everyone the uses and significance of the cutting tools with their razor-like flint edges, the hammers, the firestones, the rouge, the powder-puffs of the early stone period as well as Egyptian, Persian and other relics of more recent date. It is interesting to know that recently the Society of Pre-history has been formed to assist Dr. Ami in carrying on this work.

In the Photographic rooms a large number of lantern slides were shown; these covered the various phases of the Observatory's work, and included slides of stars, planets, solar phenomena, seismograph records, solar and stellar spectra and different instruments. The photographic printing machines and enlargers were shown and demonstrated.

In the Stellar Photometry Division was the measuring engine for determining the diameters of star images on the photographic plate, this instrument permits extremely fine measures to be made. Of special interest was a collection of lantern slides showing the growth of astronomical work in Canada, from the original equipment of the Observatory on Cliff Street, Ottawa, to the second largest telescope in the world—at Victoria. Other slides were displayed, covering the vast area from our closest neighbour, the Moon, to the Spiral Nebulae or so-called "Island Universes" far beyond the Milky Way.

In the office of the Astrophysics Division, were some interesting exhibits, explaining the work of that section. A grating, on which 20,000 lines were ruled to the inch, showed how a spectrum was formed. Typical stellar spectrograms were shown in both the direct and comparison measuring machines; the method of measuring these was explained, and the resultant radial velocity curves seen. Explanations of pulsating stars were given and spectrograms of such a star exhibited. In studying the light variation of these stars, a Photo-electric Photometer is used. This very delicate instrument was explained to the visitors and was of special interest to them.

Though a programme of interesting objects had been arranged for the guests to view with the 15-inch equatorial telescope, poor weather prevented this from being carried out. However, the telescope with its driving clock and equipment was explained and the revolving of the large dome demonstrated.

April 26—The meeting was held in the Victoria Memorial Museum. Mr. C. C. Smith, the President, was in the chair.

The lecture of the evening was given by Mr. J. H. Ogden, of Ottawa, on "Astronomy and the Layman".

The lecturer spoke as a layman to laymen, and the main object of the lecture was, first, to try to bespeak his interest in the great science, and second, to indicate a few ways by which that interest may be stimulated and fostered.

He strongly urged that the acquisition of knowledge in regard to the universe should commence in the Public Elementary Schools; that every Public School Authority should place this work in the hands of one man, with an assistant if need be, who should be peripatetic teachers of the subject and take charge of the work in all the schools in the area of that authority; that one room in a central school in that area should be made suitable for the housing and operation of a 6-inch telescope, equatorially mounted, and equipped with a driving clock; that the subject should not be treated as a subject for examination, nor for the awarding of marks or prizes, but should be conducted as a recreative occupation that will attract and please. This would lay the foundation for a future generation of laymen that will display an intelligent interest in the structure, nature and chief characteristics of the scheme of things in which they live, the knowledge of which is an indispensable part of a man's education.

The lecturer asked and answered the question as to whether the study of astronomy was, in the main, utilitarian or intellectual. He argued that when all the utilities which astronomy renders are summed up, and when we think of the utter insignificance not only of the earth, but of the whole solar system, and then proceed to think of the unfathomable abysses of space by which we are surrounded and what these abysses contain, he did not see how we could escape the conclusion that these utilities are not commensurate with the enormous outlay of labour and resources that are represented in the prodigious labours of our past and present astronomers and in the invaluable and costly aids with which our observatories and astrophysical laboratories are equipped. The only conclusion to which we are able to come is that it must be regarded as mainly an intellectual pursuit that is worthy of the very best that a man can bring to it. He argued that the facts and principles of astronomy needed to be interpreted, made plain, put before the layman in an attractive and arresting form that will arouse his interest, by means of striking similies and contrasts, and homely and

well selected illustrations, and by the skilful and attractive manipulation of figures that will bring home to him the wonderment of its phenomena and the basic principles of the science.

He also advocated, in the interest of the layman, the creation of an Astronomical Corporation for the purpose of the production and hiring to movie theatres of a list of 50 sets of films and slides on leading astronomical facts, great care being taken to make the captions an attractive and arresting feature.

The lecturer was of the opinion that, in the future, astronomy would prove to be, as Sir Edwin Arnold predicted, the chief Educator and Emancipator of the race.

A vote of thanks was tendered Mr. Ogden for his most interesting address.

M. S. BURLAND,
Secretary.

AT WINNIPEG

January 9—The regular meeting was held in Theatre "A" University Science Building, at 8.15 p.m. The President, Dr. L. A. H. Warren, was in the Chair.

The lecture of the evening was given by Professor G. M. Brownell, Ph.D., who spoke on "Volcanic Activity".

The following is a summary of the address:—

There are two phases of vulcanism, which term is inclusive of all movements of molten rock and high temperature phenomena within the earth. One is the Plutonic phase covering all sub-surface movements, the other, known as Volcanic Activity in which molten rock and gases reach the surface of the earth. The former is more important geologically, but the latter is more spectacular and terrifying.

The earth's crust is divided into continental blocks and ocean basins (level earth covered two miles or more deep with water). Notwithstanding continual erosion, the continents remain above sea level, because their density is less than that of the rocks below the oceans.

These continental and ocean blocks may be considered as separate segments of the earth's crust about 70 miles deep, each "floating" on the plastic zone below, called the "zone of compensation". Where movement takes place between separate blocks, zones of weakness or cracks are developed, sometimes referred to as "hinge zones".

Since the San Francisco earthquake in 1906, seismograph stations, established all over the world, have demonstrated by the way earthquake waves travel through the earth, that its interior is not only solid; but has a rigidity more than twice that of steel.

Temperature increases as we descend from the earth's surface till at 100 or 200 miles below, it is probably between 2,000° and 3,000° C. Rock at that depth, however, is under such an immense pressure that ordinarily it cannot expand and melt, hence we have a solid rock at high temperature within the earth.

There are two ways, however, in which rocks at great depths may melt: 1st, sufficient extra heat may be developed locally by the friction of mountain folding to melt rocks, as evidenced by the volcanic activity frequently accompanying such crushing and sliding of mountain masses. 2nd, relief of pressure by a crack in the earth's crust may allow the adjacent rocks to expand and melt into large reservoirs of liquid rock which, while still below the surface, are called a "magma".

The earth's hinge zones are specially favourable for the formation of such a magma. If it does not reach the surface but cools slowly, crystallizing into a solid mass, then we will have a granite or some similar plutonic rock. A magma, however, is not simply molten rock, as there are also great quantities of gases present, especially steam. These gases tend to escape and, if possible, force their way to the surface. If a connection is made with the surface through which gases and molten rock can escape, then we have volcanic activity. Because magmas form along the hinge zones, we find that volcanoes are usually located along lines and not distributed over broad areas.

When a molten magma forces its way up to the surface, it will continue to pour out molten rock (lava) until all pressure is relieved, and then it will die down, but the gases will still keep on bubbling out.

In an active volcano like Kilauea, in the Hawaiian Islands, the hot gases rising from great depths keep the lava at the surface at a high temperature, alternately falling and boiling over, and as some of the gases are inflammable, they burst into flames as they reach the surface.

When a magma is cooling and the gases not coming off with sufficient force to keep the pipe open, it may freeze over and the volcano become dormant until the gas accumulated below regains pressure enough to burst through as a volcanic explosion once more. Thus we have an intermittent volcano.

Long after a volcano has become extinct, fumaroles, hot springs and geysers may remain active, proving the still high temperature of the rocks a little below the surface.

Products of Volcanoes—Gases; water in the form of steam is by far the most abundant. A study of Mt. Etna showed that over 4½ million gallons of water were discharged daily from one small cone. In fact it is judged that most of the water now in the oceans has thus been derived from the rocks.

Liquid: Lava differs from magma in that it has lost its gases and water.

Black basaltic lava is very fluid and has been seen to flow for 100 miles in Iceland.

Solid: Fragmental material may consist of fragments torn from the sides of a vent, fragments of solidified lava in the crater, or masses of lava thrown up in the air and solidified as they fell.

Fissure Eruption: Fissures through which lava flows in great volume are called fissure eruptions. The greatest outpourings of lava in geological history are of this type. There are several large fissures in Iceland, some 19 and 20 miles long, open to depths of 400 to 650 feet. One Iceland flow covers 270 square miles. Successive vast outpourings of lava have built up extensive plateaus in the past. Evidences of such outpourings may be seen in some of the Western United States, in Deccan, India, Africa and Brazil. The Keewatin Greenstone in the Hudson's Bay Shield have had a similar origin.

Volcanic Eruptions: Explosive; Gases are the main factor and solid fragments and dust the result. When gas blows out without much explosive force, it often builds up steep volcanic cones of ash.

Effusive: The more fluid the lava, the more gentle will be the slope. The best example of this is Mauna Loa, the largest single cone in the world, having been built up from the ocean floor to a height of over 30,000 feet, the top being 13,000 feet above sea level. Its base is 100 miles in diameter.

At the conclusion of the lecture, which was illustrated by many fine slides, the speaker answered a number of questions.

Dr. Warren expressed the thanks of the Society to Dr. Brownlee.

S. C. Norris,
Secretary.

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